Recent Developments in the GFDL-AM3 Model

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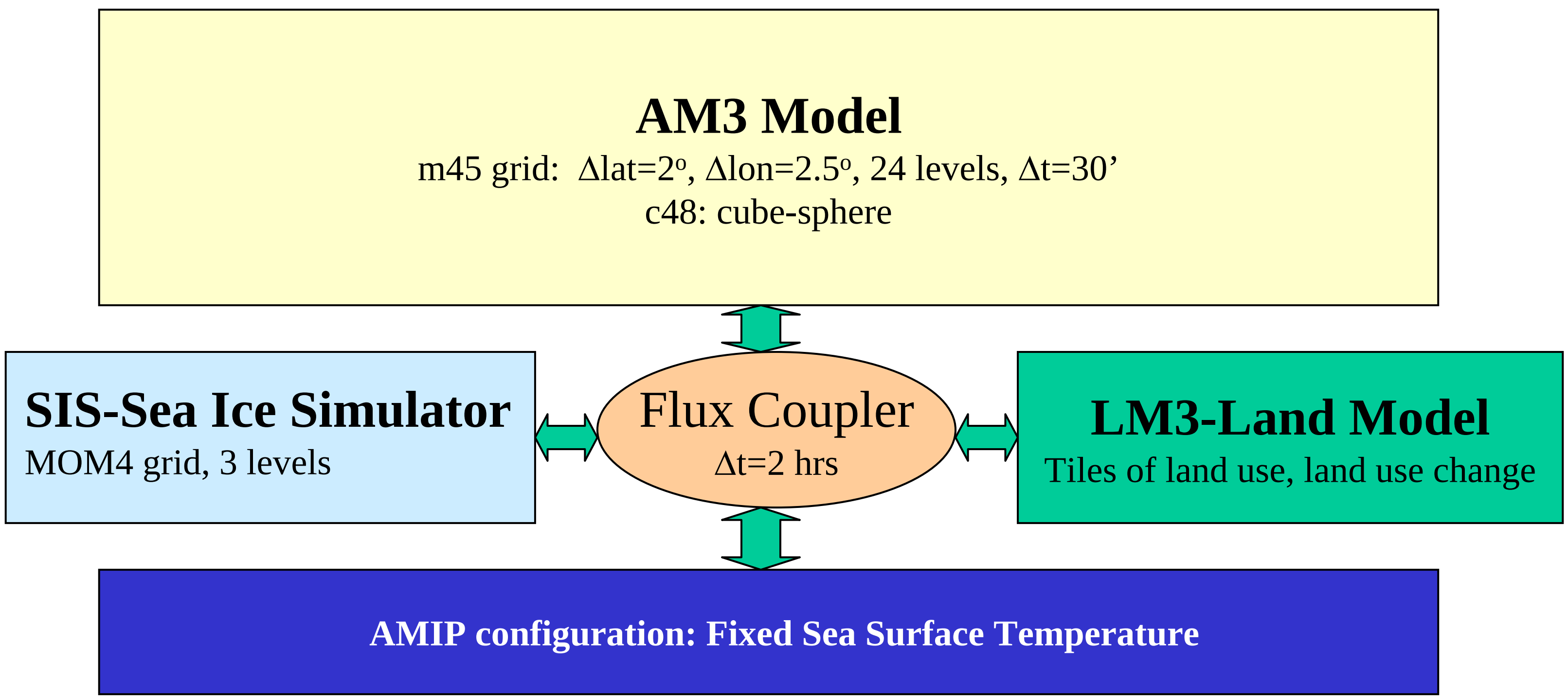
I. Model description

- Configuration of the coupled models
- What is new in AM3 compare to AM2 (GAMDT, 2006) used in CM2.1 for IPCC AR-4 simulations
- Description of chemical tracers

GFDL-AM3 configuration



What's new in AM3

- **Deep convection**: Arakawa-Schubert (Moorthi and Suarez, 1992) => Donner scheme (Donner, 1993)
- **Shallow convection**: Arakawa-Schubert => UW shallow (Roode and Bretherton, 2003)
- **Planetary boundary layer**: Anderson et al. (2004) unchanged
- **Stratiform clouds**: Tiedke (1993) unchanged
- **Cloud droplet numbers**: fixed values over land and ocean => prognostic equation (Ming et al., 2007) of Nd
- **Chemistry**: gas species and aerosols, calculated off-line (Horowitz et al., 2006) => prognostic equations for all transported species, based on MOZART (Horowitz et al, 2003) for gas phase, and GOCART (Chin et al., 2000; Ginoux et al. 2001) for aerosols.

What’s new in AM3 cont’d

- **Radiation**:
  - SW (Freidenreich and Ramaswamy, 1999): unchanged
  - LW (Schwarzkopf and Ramaswamy, 1999): unchanged
  - Gas species and aerosols: off-line => on-line
  - Aerosol optical properties: α_{SO4}(RH), α_{SS}(80%)=>α_{SO4}(RH), α_{SS}(RH), α_{OCphyl}(RH), k(dust) reduced in visible
  - Clouds: maximum overlap of stratiform clouds => stochastic overlap of stratiform, shallow and deep convective clouds
- **Advection**: m45 Finite Volume (Lin, 2004) => C48 Cube sphere
- **Vertical levels**: 24 => 48 (most of the additional levels in the stratosphere)
- **Nudging capability**: New capability: u, v, T, q, p_s may be nudged by a relaxation method, towards NCEP re-analysis

Chemical tracers in AM3

- Gas phase:~100 species, ~225 reactions (with all species and reactions active throughout the atmosphere), lookup table for photolysis rates, parameterized source of halogens in the stratosphere, full treatment of PSCs.(Horowitz et al., 2003; 2006; Austin et Wilson, 2007)
- Aerosol mass distribution:
  - 15 prognostic equations (not including gas species)
  - 5 species: SO_4 (log-normal), OC (log-normal), BC (log-normal), SS (5 bins from 0.1 to 10μm), DU(5 bins from 0.1 to 10 μm)
  - Aging:
    - $OC_{hydrophobic}$ -> $OC_{hydrophylic}$ (2 days),
    - $BC_{hydrophobic}$-> $BC_{hydrophylic}$ (1 day)
  - SO_4 chemistry: aqueous and gas phases calculate with full chemistry code (MOZART). Option to use simplified sulfate with prescribed O_3, NO_3, OH, H_2O_2

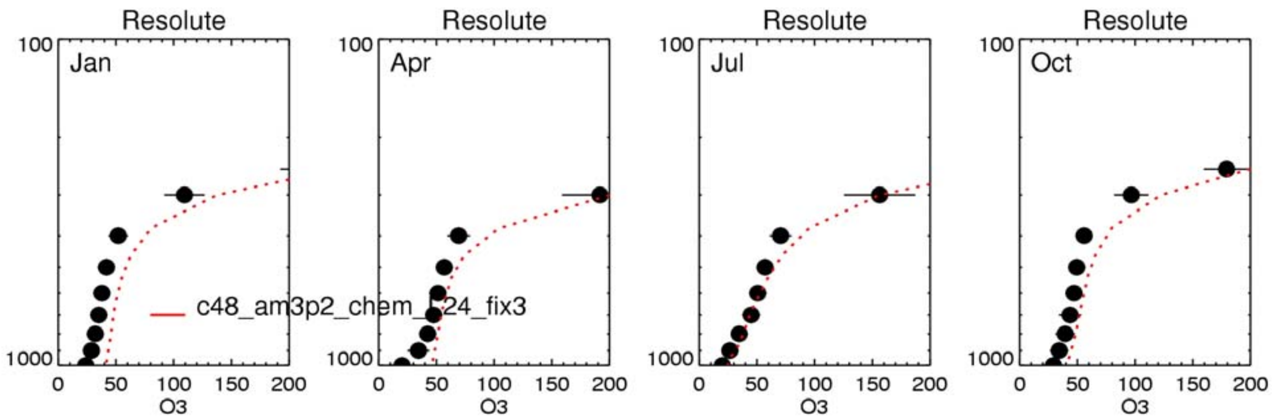
Model evaluation

- Vertical resolution on tropospheric O_3
- Nudging on aerosol concentration
- Mixing state on aerosol absorption
- Limiting hygroscopic growth on aerosol distribution
- Comparison of aerosol concentration and optical depth with ground based and remote sensing data.

Effect of increased vertical resolution on O3 profiles

Comparison of O_3 vertical profiles with O_3-sondes.

L24



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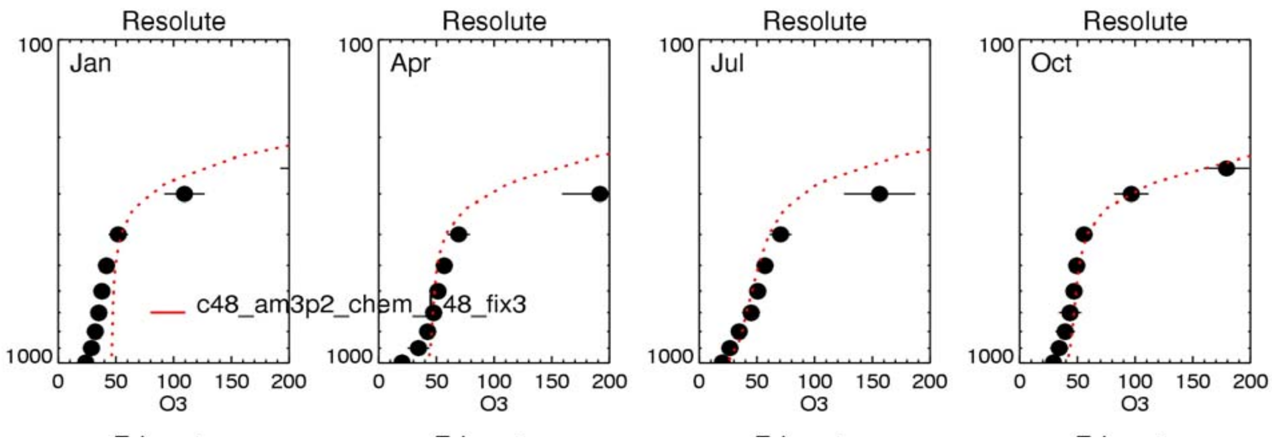
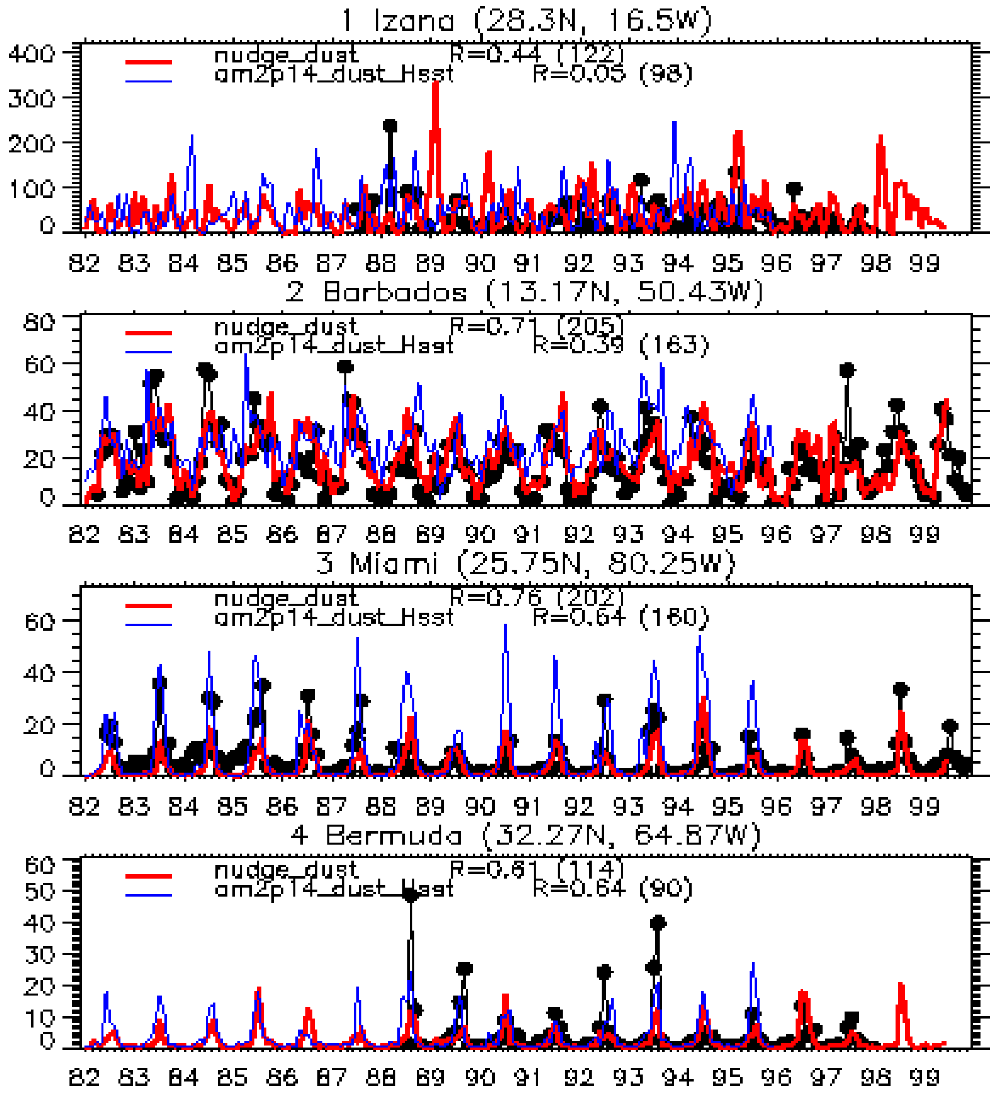


Effect of nudging u, v, T, and p_s on aerosol concentration

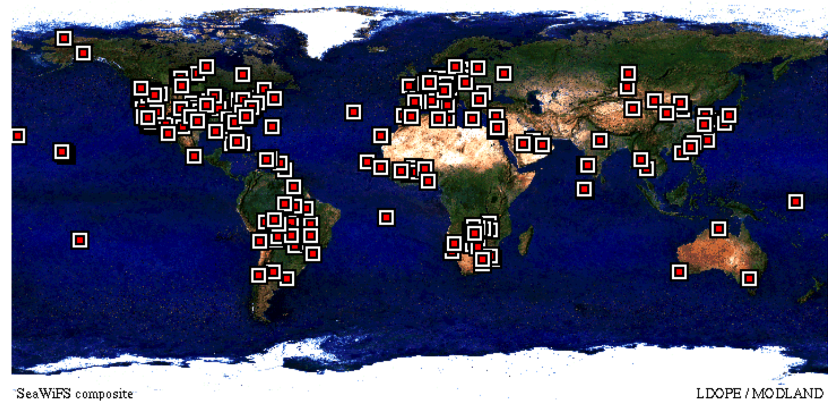


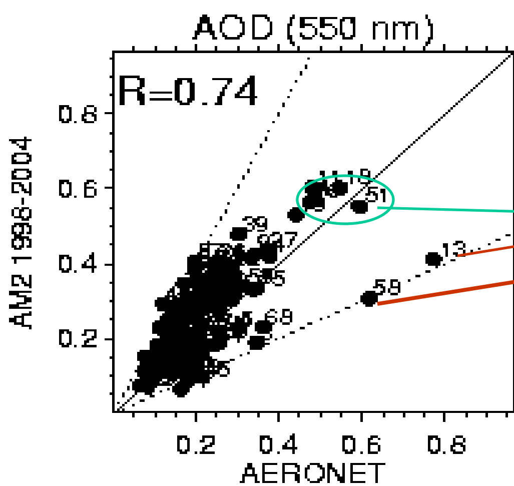
	R
AM2n Izania	0.44
AM2 Izania	0.05
AM2n Barb	0.71
AM2 Barb	0.39
AM2n Miami	0.76
AM2 Miami	0.64
AM2n Bermuda	0.61
AM2 Bermuda	0.64

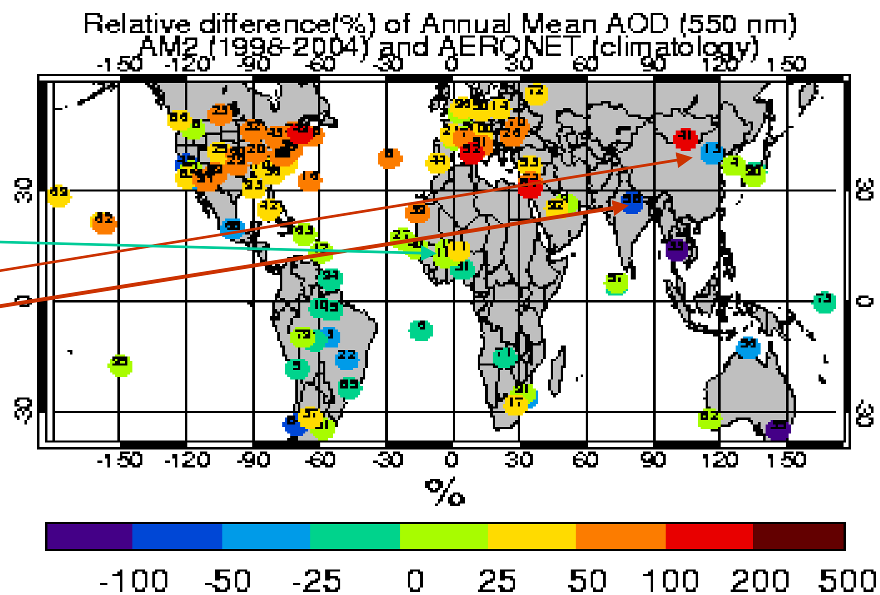
Comparison of AOD with AERONET data

Automatic sunphotometer CIMEL

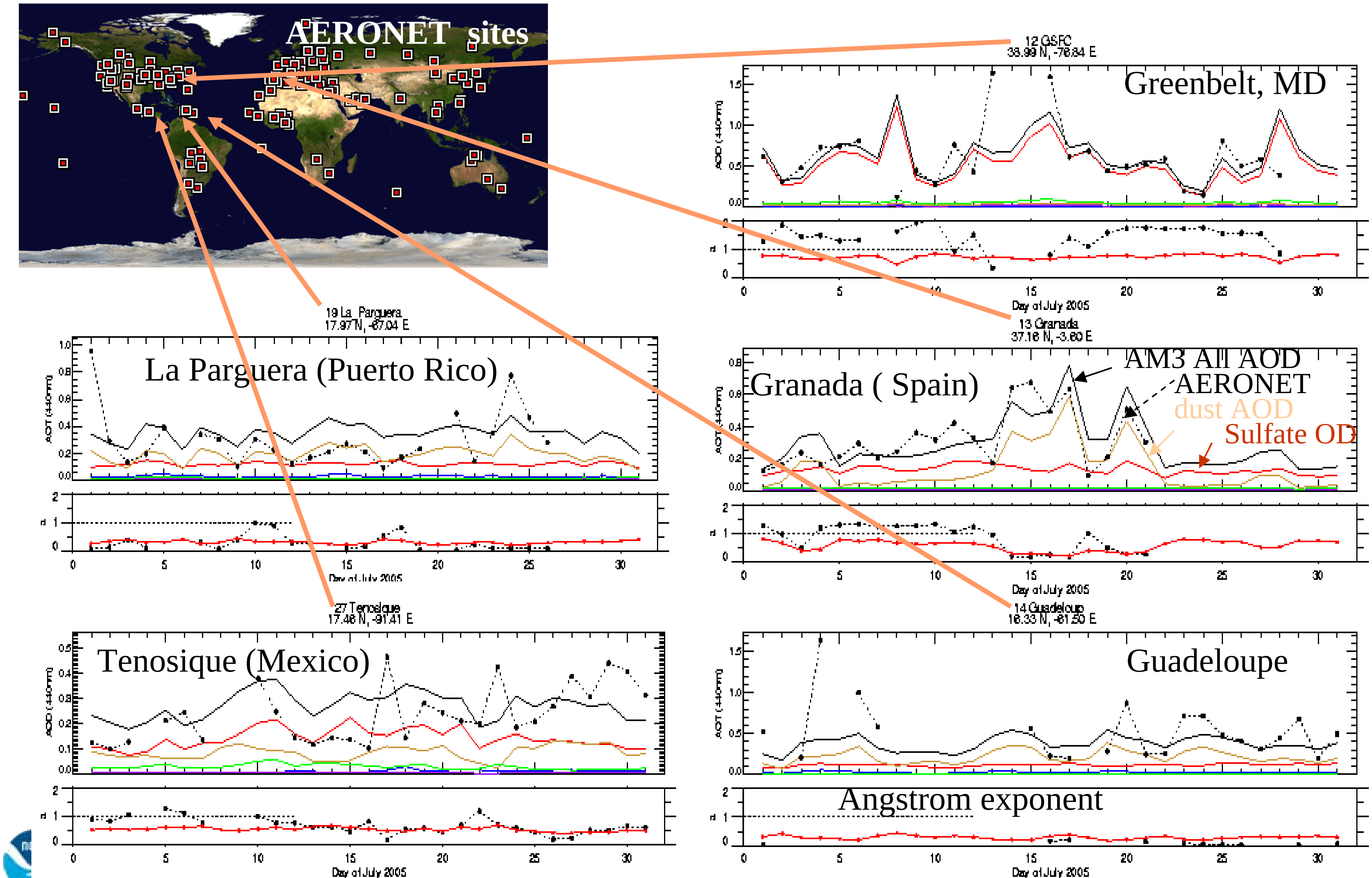
- τ at 340, 378, 499, 613, 870, 940, 1020nm filters
- Accuracy: 0.01-0.02
- Triplet data every 35 seconds
- From 1993, now more than 200 instruments
- Almacuntar and Principal plane sky radiance
  Inverse algorithm: size, m, ω for 2 modes



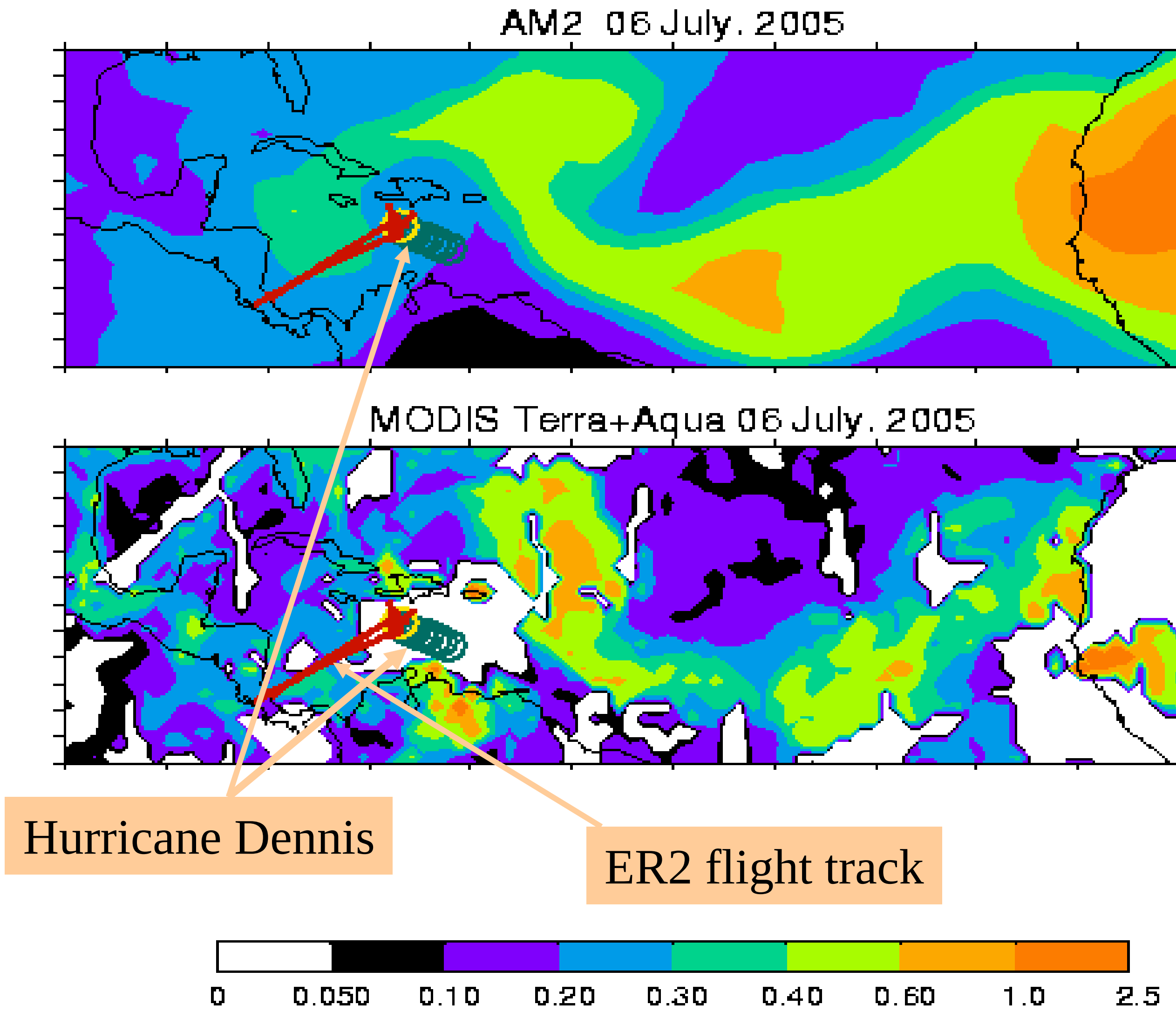




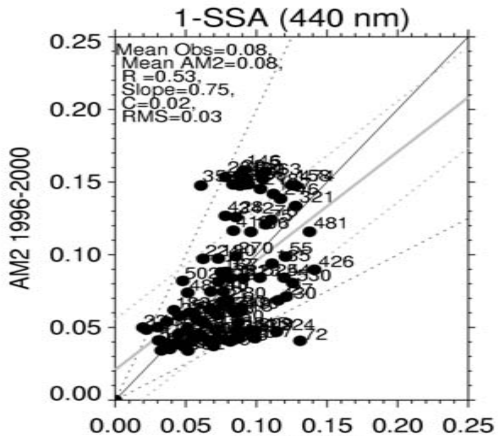
Effect of nudging on daily variability of AOD during TCSP field campaign



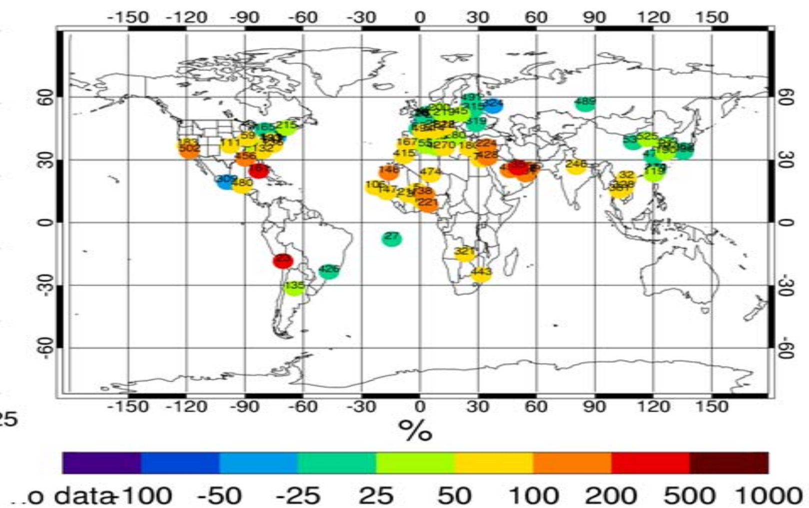
Simulation of daily AOD for TCSP



Effect of mixing on aerosol absorption properties

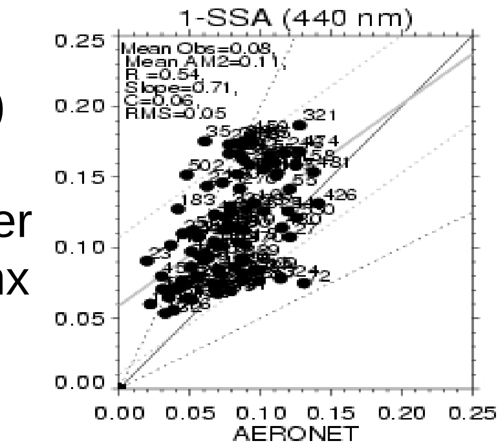


1-w(440) AERONET

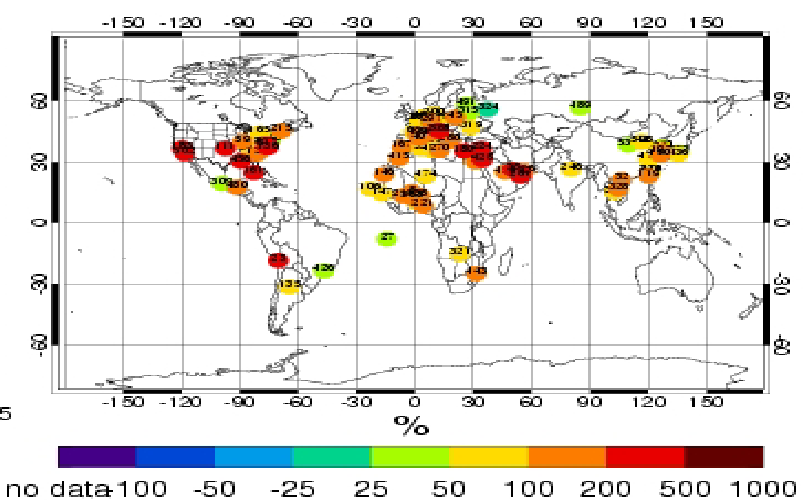


Relative difference (%) model-observation

1-w(550)
AM3
Off-line Aer
Internal mx

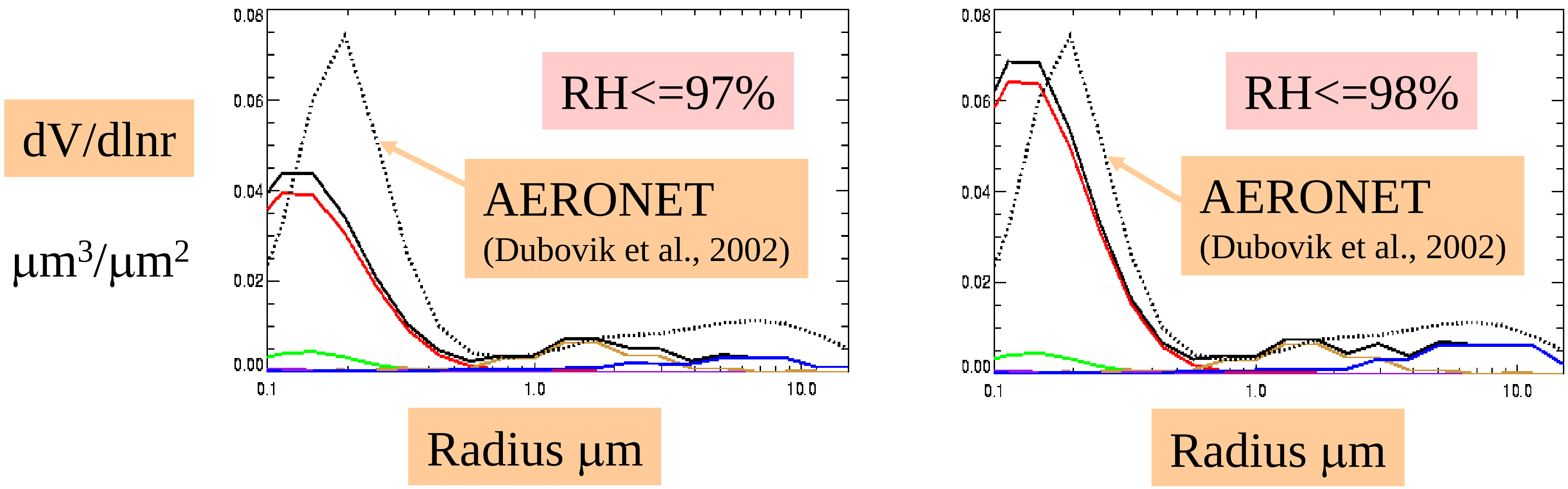


1-w(440) AERONET

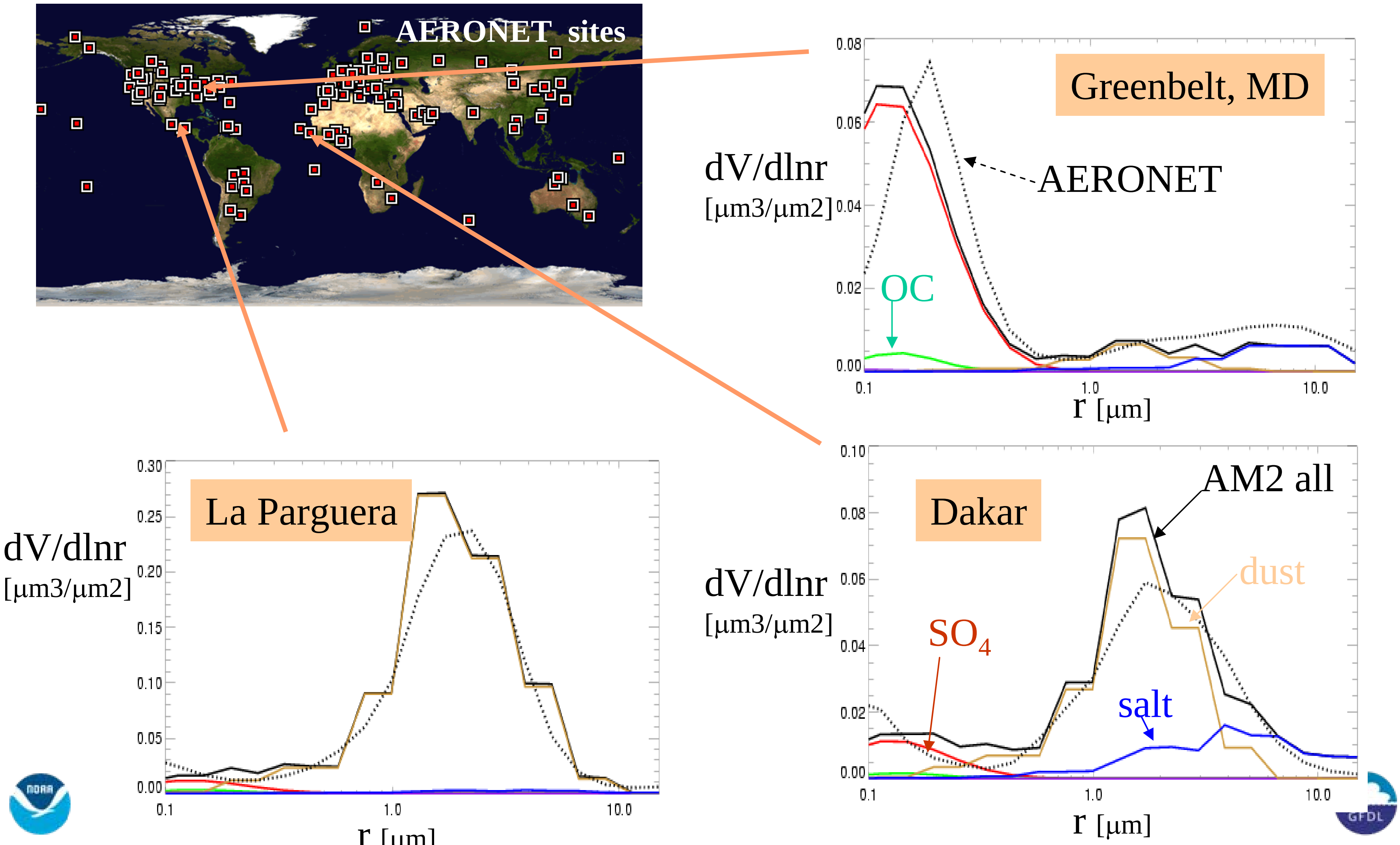


Effect of limiting hygroscopic growth on aerosol size distribution

Volume size distribution, J-J-A (2004) Greenbelt, MD

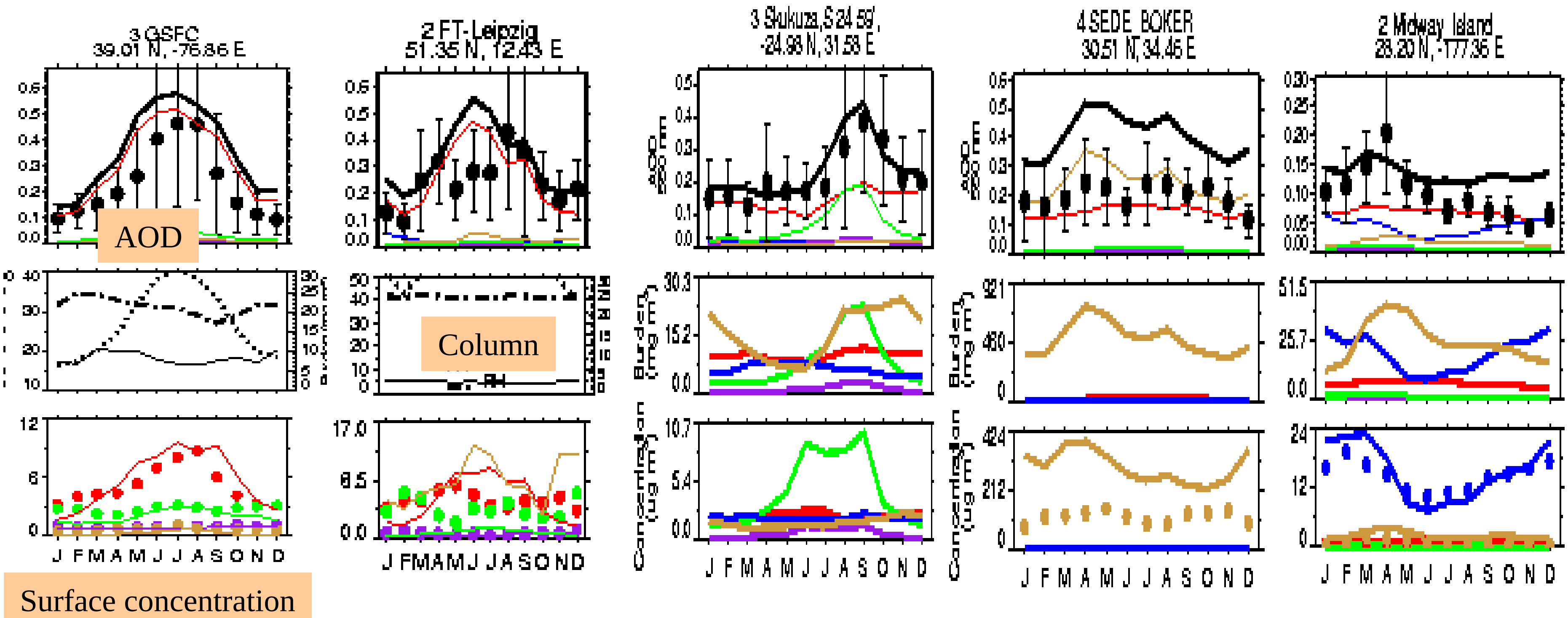


Aerosol Size distribution: AM3/AERONET



Analysis of aerosols by Regions

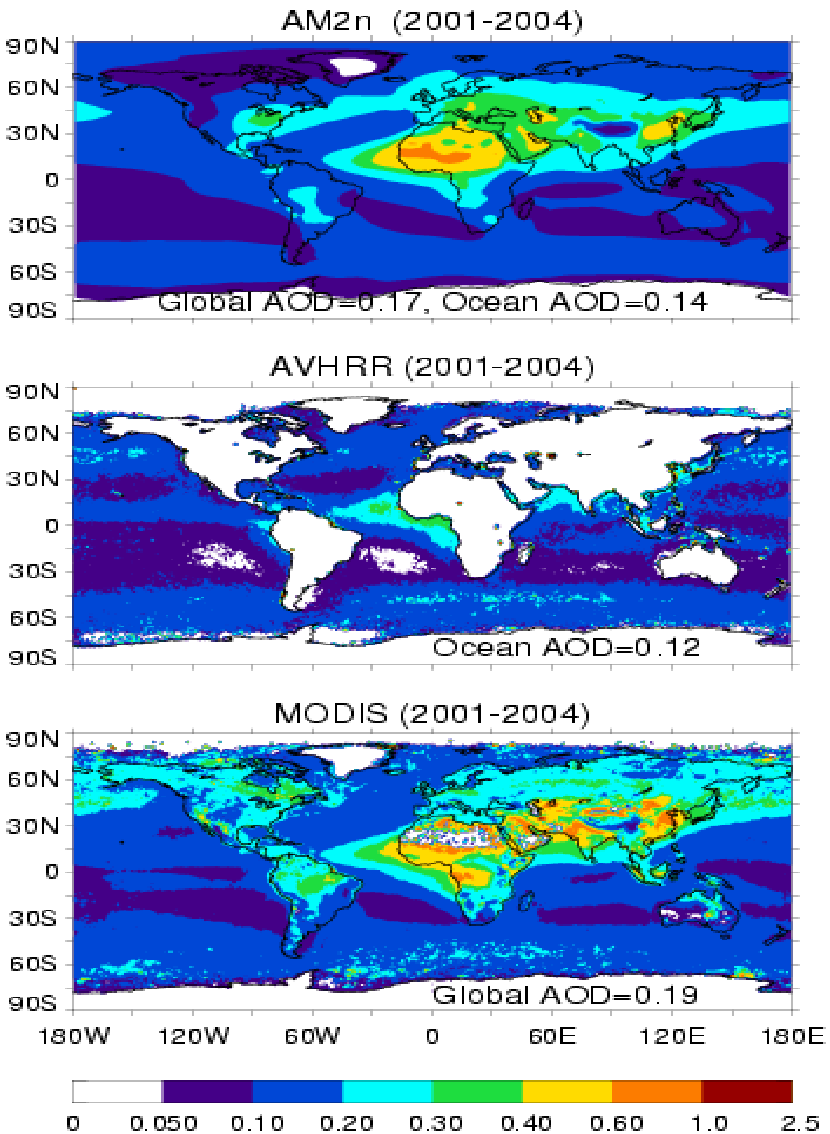
US | Europe | Bio Burning | Dusty | Maritime



AOD is over-estimated in Mediterranean basin due to DU conc.

α=f(RH<= 98%) seems to provide AOD within σ of AERONET data

Comparison of AOD with AVHRR and MODIS

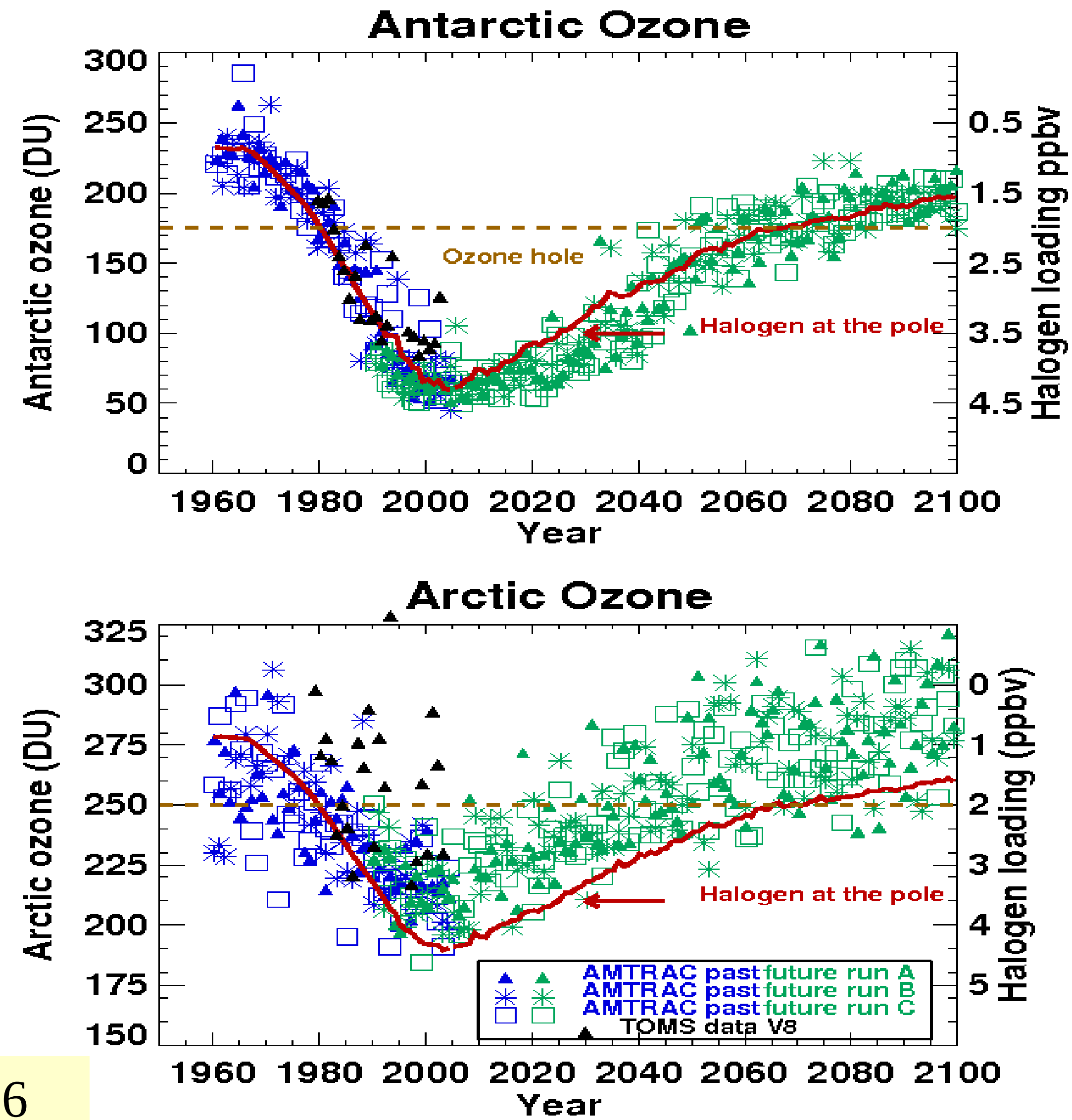


III. Three examples of applications

- Stratospheric O3 recovery (Austin and Wilson, JGR, 2006)
- Effect of decadal variability of dust on NAO (Ginoux et al., Yoram Kaufman special issue of JGR)
- Interpreting dust variability in Antarctic ice-core: work with PhD student Fuyu Li (Princeton University), to be present at A-train symposium, Lille, October 2007.

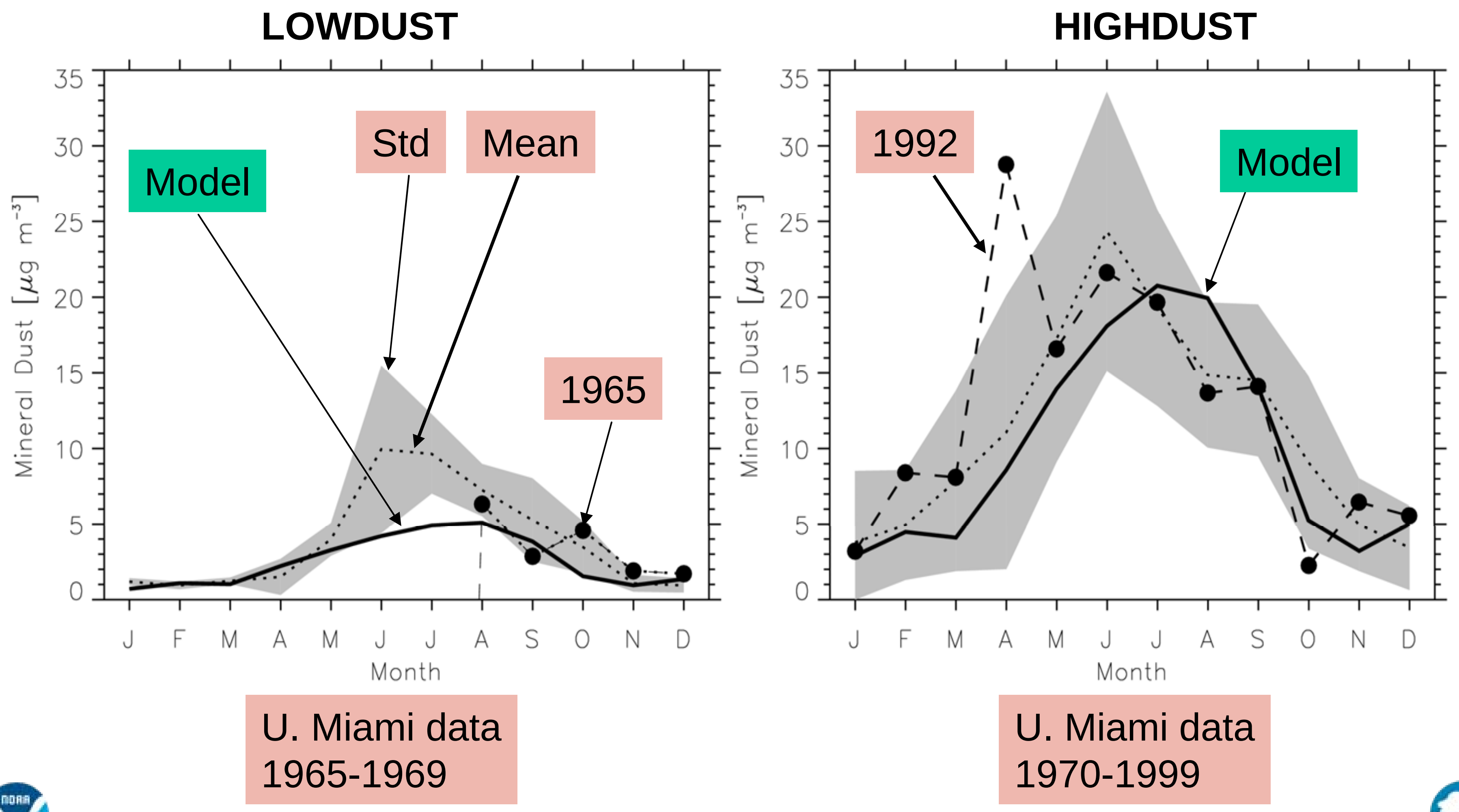
Application 1:Recovery of stratospheric ozone

Simulated and observed minimum spring total ozone 1960-2099



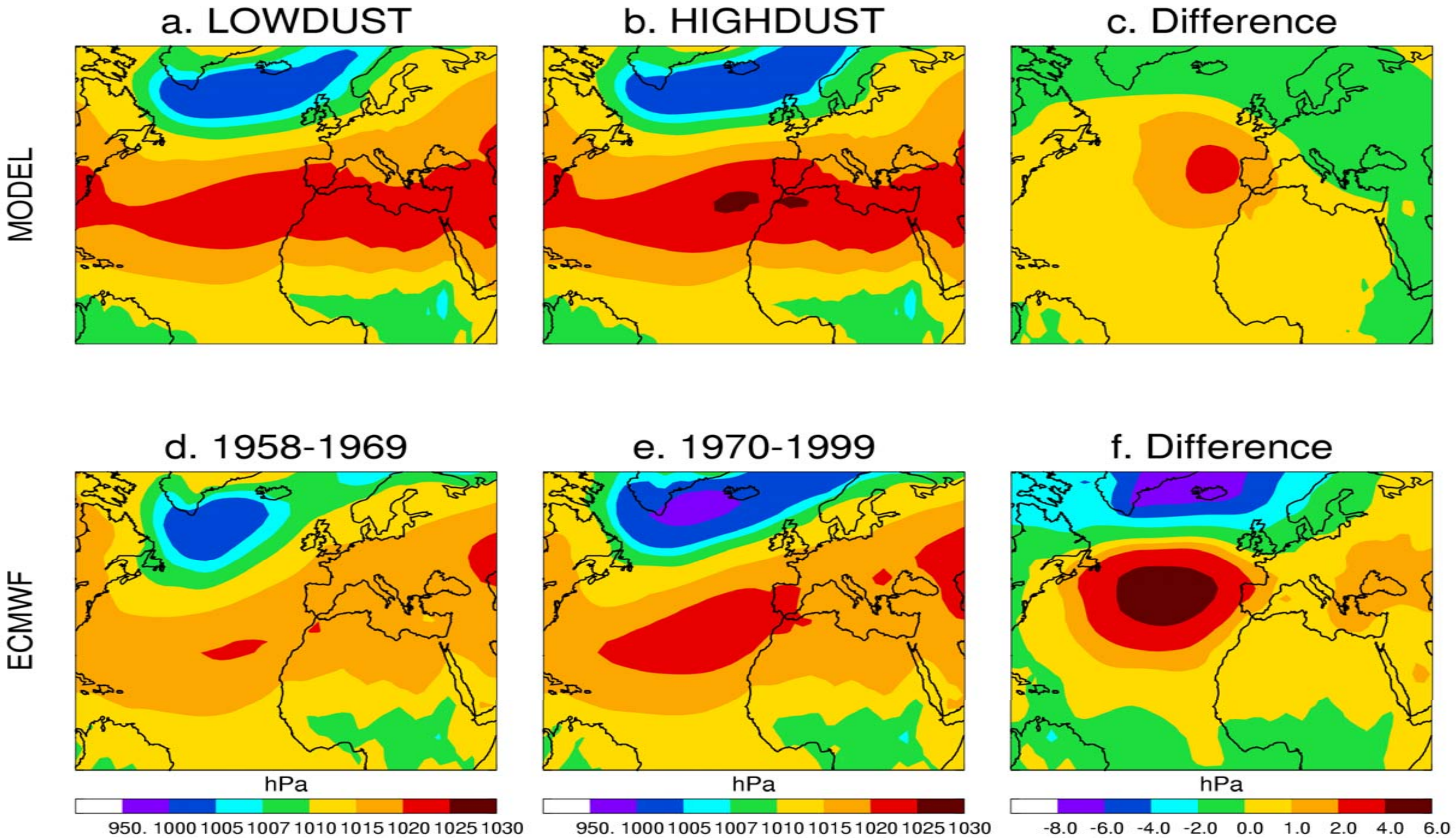
Austin and Wilson, JGR, 2006

Application 2: Dust and NAO



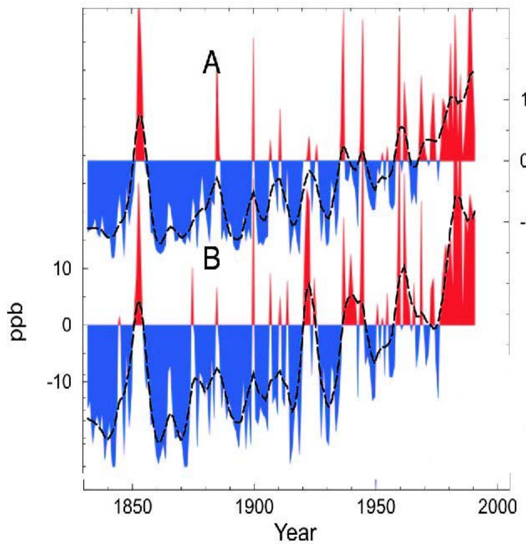
Application 2: cont'd

Sea Level Pressure D-J-F

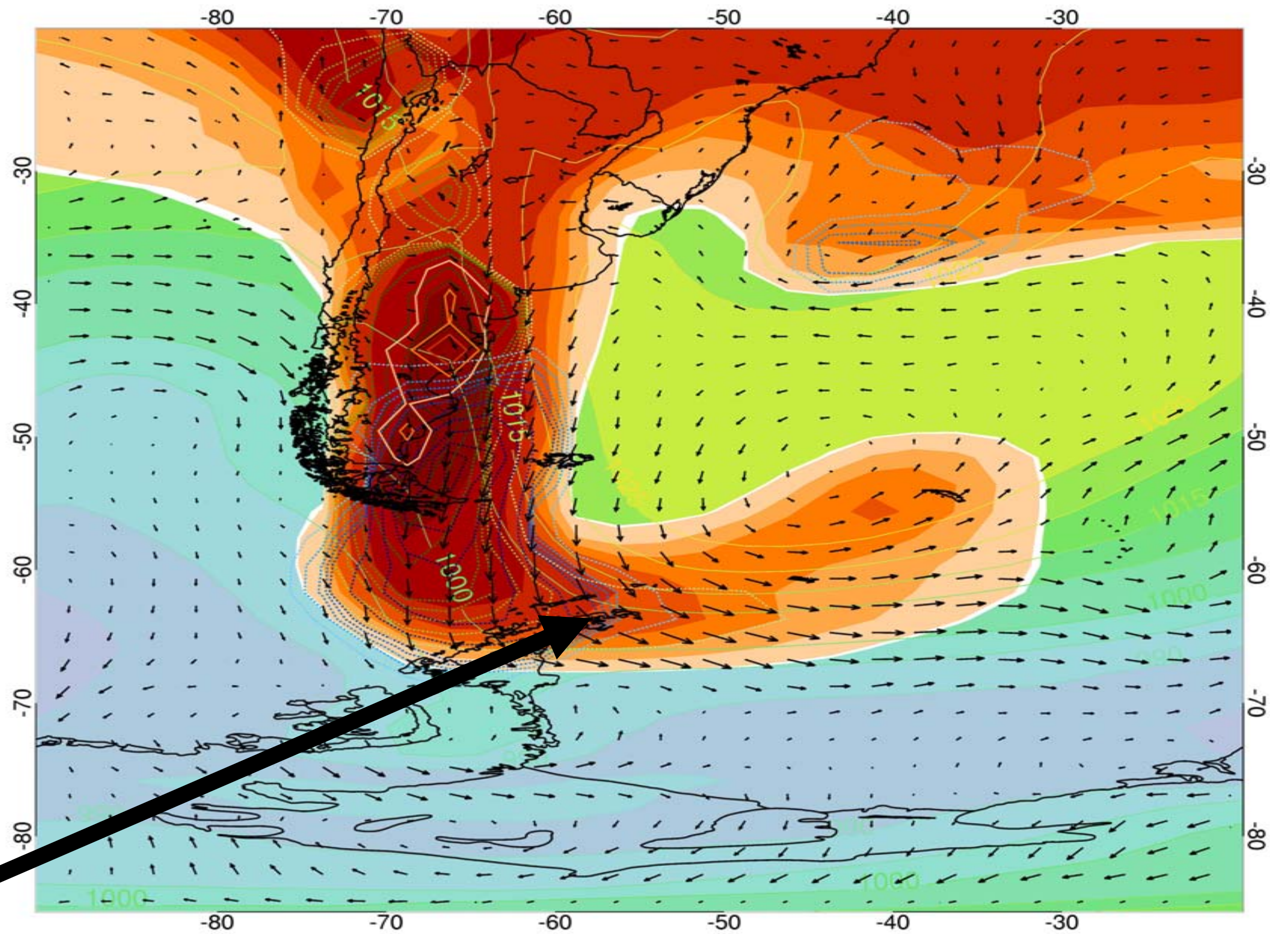


Application 3: Dust in Antarctic ice-cores

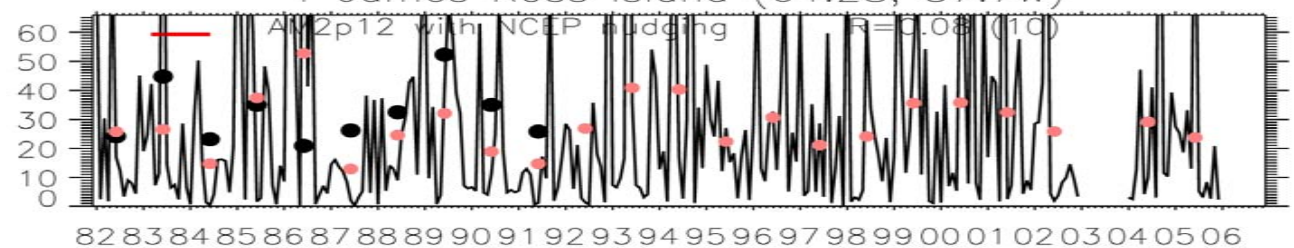
Time series of dust in Ross-Island icecore



McConnell et al., PNAS,2007



Ross Island



Conclusions

- Simulated agree surprisingly well in simulated AOD at the global scale
- Closure look, shows regional discrepancies and strong sensitivity of hygroscopic property of aerosols in polluted regions
- The use of maximum RH for hygroscopic growth of aerosols correspond to tune model results to fit the measurements, in particular AERONET data
- The discrepancies of AOD between AERONET and satellite data (MODIS) are unexplained, and the consistency between models and AERONET seems therefore not fortuitous in polluted regions
- Succession of comparisons allow to validate several key parameters, but does not allow to understand some major discrepancies. The comparisons should be made simultaneously on all datasets (merged datasets).
- For global models, satellite data and network of well calibrated instruments are the most usefull but the limit number of variable retrieved by these instruments necessitate super-sites.
- For climate model, long term datasets are crucial, but only a handful of aerosol sites have been operating before the eighties